US009058832B2

(12) United States Patent
Albrecht et al.

(10) Patent No.: US 9,058,832 B2
(45) Date of Patent: Jun. 16, 2015

(54) **METHOD OF MANUFACTURING A BIT PATTERNED MEDIA ON A MAGNETIC MEDIA DISK**

(75) Inventors: **Thomas Robert Albrecht**, San Jose, CA (US); **Olav Hellwig**, San Jose, CA (US)

(73) Assignee: **HGST NETHERLANDS B.V.**, Amsterdam (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 414 days.

(21) Appl. No.: **13/362,510**

(22) Filed: **Jan. 31, 2012**

(65) **Prior Publication Data**

US 2012/0128871 A1 May 24, 2012

Related U.S. Application Data

(62) Division of application No. 11/957,981, filed on Dec. 17, 2007, now Pat. No. 8,130,468.

(51) **Int. Cl.**

G11B 5/855	(2006.01)
C23C 14/22	(2006.01)
B82Y 10/00	(2011.01)
G11B 5/74	(2006.01)
G11B 5/82	(2006.01)

(52) **U.S. Cl.**

CPC ***G11B 5/855*** (2013.01); ***C23C 14/22*** (2013.01); ***C23C 14/225*** (2013.01); ***C23C 14/226*** (2013.01); *Y10T 29/49021* (2015.01); *Y10T 29/49069* (2015.01); ***B82Y 10/00*** (2013.01); ***G11B 5/743*** (2013.01); ***G11B 5/82*** (2013.01)

(58) **Field of Classification Search**

CPC G11B 5/82; G11B 5/855; G11B 5/743; B82Y 10/00; C23C 14/22; C23C 14/225; C23C 14/226; Y10T 29/49021; Y10T 29/49069

USPC 29/603.01, 604; 427/127, 128, 255.23, 427/255.27, 255.7; 428/826, 827, 836

See application file for complete search history.

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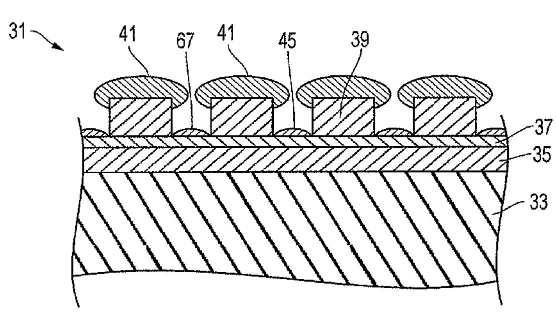
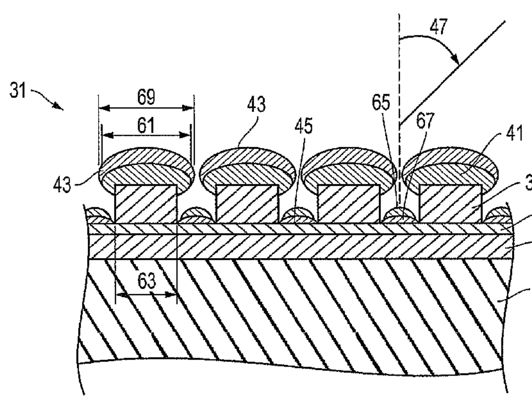
Primary Examiner — A. Dexter Tugbang

(57) **ABSTRACT**

A method of forming a bit patterned media on a magnetic media disk may include forming topographic features on a substrate and defining trenches therebetween. The method also may include forming non-magnetic material on the topographic features to define non-magnetic portions. In addition, magnetic material may be formed on the non-magnetic portions to define magnetic portions for a recording layer, such that the magnetic portions have a magnetic width that is greater than a non-magnetic width of the non-magnetic portions.

10 Claims, 3 Drawing Sheets





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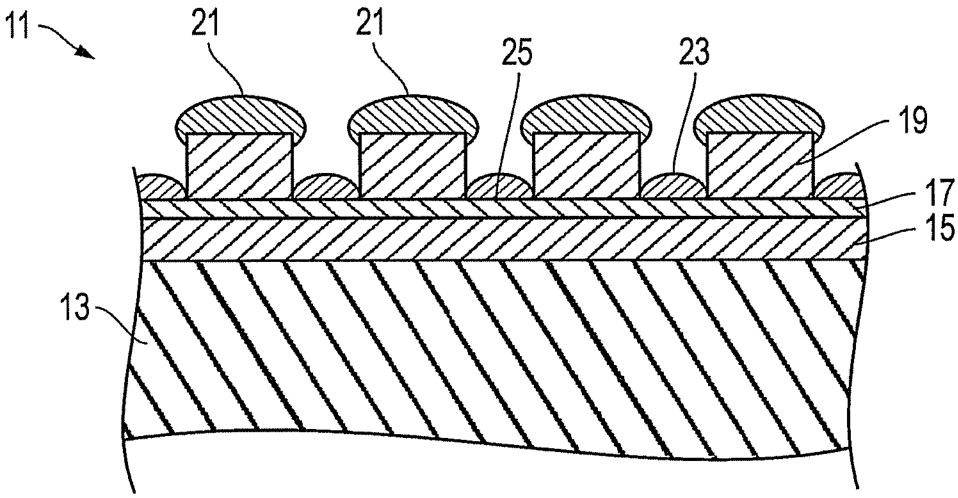


FIG. 1
(Prior Art)

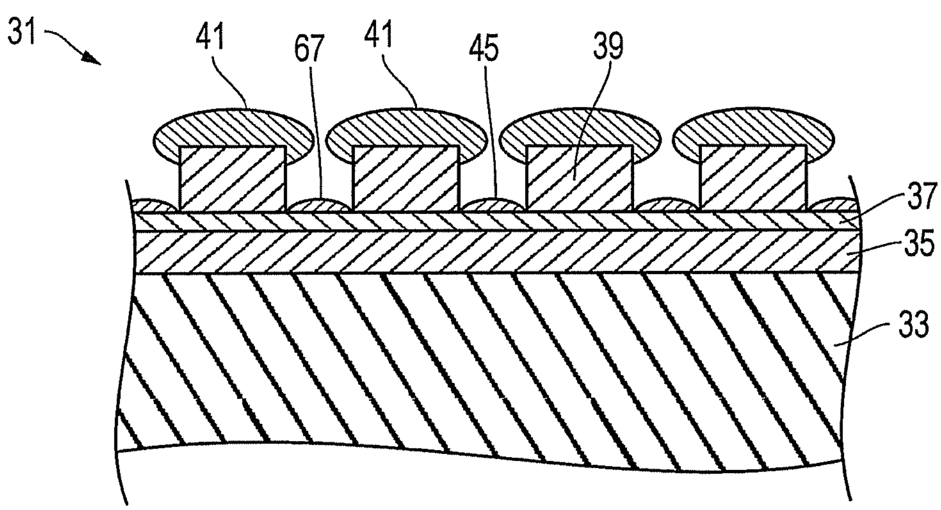
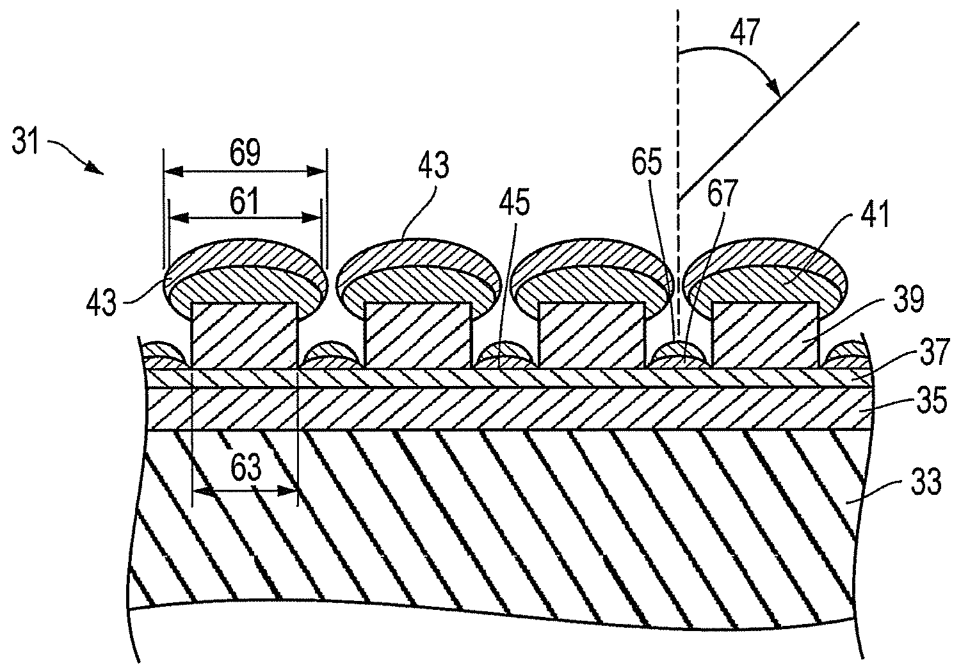


FIG. 2


31
69
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33

FIG. 3

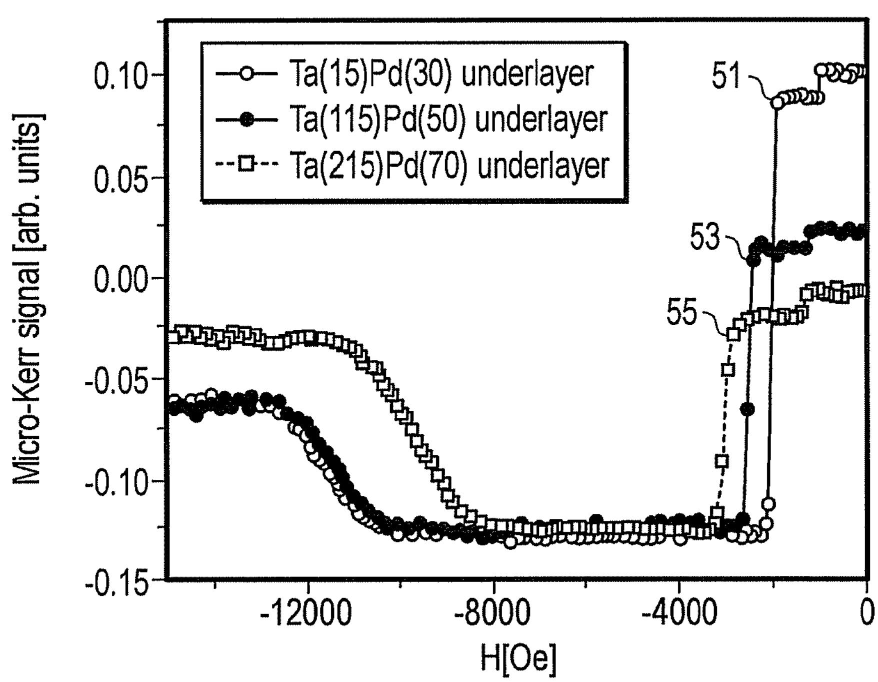
Ta(15)Pd(30) underlayer
Ta(115)Pd(50) underlayer
Ta(215)Pd(70) underlayer
51
53
55
Micro-Kerr signal [arb. units]
0.10
0.05
0.00
-0.05
-0.10
-0.15
-12000
-8000
-4000
0
H[Oe]

FIG. 4

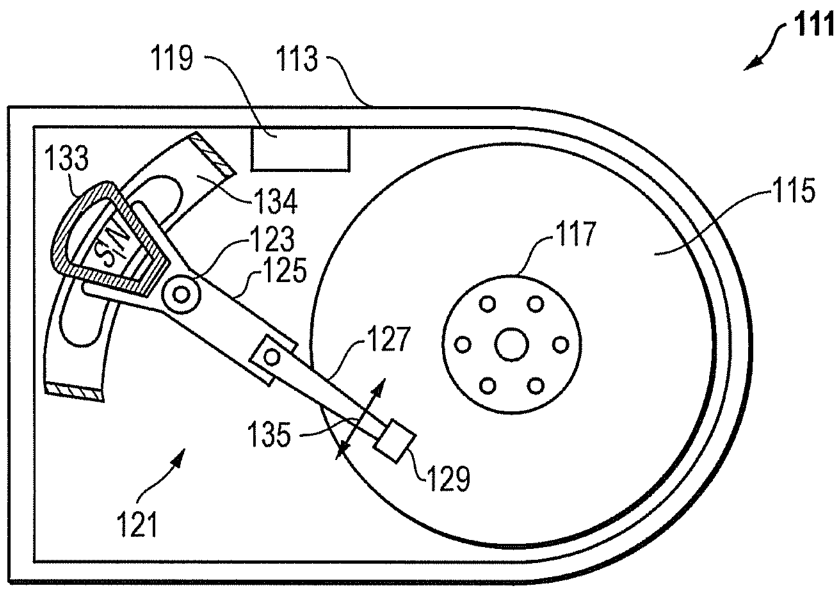

FIG. 5

METHOD OF MANUFACTURING A BIT PATTERNED MEDIA ON A MAGNETIC MEDIA DISK

CROSS-REFERENCE TO RELATED APPLICATION(S)

The present application is a divisional from U.S. patent application Ser. No. 11/957,981, filed Dec. 17, 2007, entitled "SYSTEM, METHOD AND APPARATUS FOR PATTERNED MEDIA WITH REDUCED MAGNETIC TRENCH MATERIAL," naming inventors Thomas Robert Albrecht and Olav Hellwig, which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates in general to patterning magnetic media for hard disk drives and, in particular, to an improved system, method and apparatus for hard disk drive patterned magnetic media having a reduced amount of magnetic trench material.

2. Description of the Related Art

Data access and storage systems generally comprise one or more storage devices that store data on magnetic storage media. For example, a magnetic storage device or hard disk drive (HDD) includes one or more disks and a disk controller to manage operations concerning the disks. The hard disks themselves are usually fabricated from an aluminum alloy, glass or a mixture of glass and ceramic, and are covered with a magnetic media coating that contains the bit pattern.

One common approach to making the bit patterned media (BPM) or discrete track media (DTM) on the disks is to create topographic patterns on the substrate, followed by blanket deposition of the magnetic recording layers. Magnetic material deposited on the tops (or "lands") of topographic features is used for recording, while material deposited in the etched relief areas (or "trenches") is not intended to be used for recording.

However, it has been shown through both modeling and experiments that magnetic material located in the trenches produces significant unwanted magnetic flux, which interferes with the readback signal. The present invention seeks to reduce the amount of magnetic material ending up in the trenches and thereby to reduce readback interference caused by the trench material.

Referring to FIG. **1**, a schematic sectional side view of a disk **11** having conventional patterned media formed on a substrate **13** is shown. The media includes a soft underlayer **15**, an exchange break layer **17** and non-magnetic pillars **19** or raised track structures having trenches **25** therebetween. A magnetic layer is blanket deposited on the topographically patterned substrate. This deposition forms a magnetic recording layer **21** (i.e., formed as "islands") on the pillars **19**, and some magnetic material **23** in the trenches **25** between the pillars **19**. The magnetic material **21** deposited on top of the pillars **19** is used for recording, while the trench material **23** generates unwanted magnetic flux that increases the background noise level and interferes with readback operations of the disk drive.

The amount of magnetic material in the trenches can be reduced by depositing the magnetic material at an angle with respect to normal incidence. However, angled deposition does not completely eliminate the trench material due to the complex, three-dimensional shapes of the pillars (particularly for BPM), and the fact that sputter deposition has only limited directionality. Furthermore, angled deposition can result in significant deposits on the sidewalls of the topography, which also has unintended effects on the magnetic properties of the islands or tracks.

An alternative solution to this problem is to "poison" the trench material. Poisoning the trench material is attractive from the point of view of totally eliminating the magnetism of the trench material. However, there are some challenges to successfully implementing such an approach for small feature sizes, including the effects of dimensional distortion of feature shapes due to diffusion processes. Thus, an improved solution for reducing the unwanted effects of having magnetic media located in the trenches between the topographic features of disks would be desirable.

SUMMARY OF THE INVENTION

Embodiments of a system, method and apparatus for reducing the amount of magnetic material located in the trenches between topographic features in bit patterned media are shown. The invention reduces or eliminates the readback interference caused by the trench material. Although the invention described herein may leave a small amount of magnetic material in the trenches, no diffusion is used. Therefore the negative consequences of diffusion are eliminated when scaling down the island size to densities beyond what is currently achieved in conventional perpendicular recording demonstrations.

In one embodiment, an intermediate and significantly thicker non-magnetic layer is deposited on the topography prior to depositing the functional magnetic layer on the topographic substrate features. Thin seed layers, underlayer structures and/or adhesion layers may be deposited directly beneath the magnetic layer, either above or below the intermediate layer. The non-magnetic layer has the effect of increasing the lateral diameter of the land regions that will ultimately support the functional magnetic layer. This also increases the effective area filling factor of magnetic material that contributes to the readback signal. In addition, the non-magnetic layer reduces the amount of trench deposition that can occur in the subsequent deposition of the magnetic recording layer. By eliminating most of the magnetic trench material, the amount of magnetic flux and readback interference produced by the trench material is reduced to an acceptable level.

Even if the non-magnetic material is incidentally deposited on the side walls, it will not cause any undesired effects, such as those experienced with magnetic materials. Overall the degree of sidewall overgrowth effects can be mitigated by varying the deposition angle with respect to the surface normal of the substrate.

The magnetic properties of the recording layers are fairly independent of the non-magnetic interlayer thickness. For example, TaPd alloys or Ta/Pd bilayers may be used for the non-magnetic layer to fulfill this requirement.

The foregoing and other objects and advantages of the present invention will be apparent to those skilled in the art, in view of the following detailed description of the present invention, taken in conjunction with the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features and advantages of the present invention are attained and can be understood in more detail, a more detailed description of the invention may be had by reference to the embodiments that are illustrated in the appended drawings. However, the drawings illustrate only some embodiments of the invention and therefore are not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

FIG. **1** is a schematic sectional side view of conventional patterned media for a magnetic media disk;

FIG. **2** is a schematic sectional side view of one embodiment of a sub-assembly of patterned media for a magnetic media disk before deposition of the magnetic layer, and is constructed in accordance with the invention;

FIG. **3** is a schematic sectional side view of one embodiment of the patterned media of FIG. **2** after deposition of a magnetic recording layer and is constructed in accordance with the invention;

FIG. **4** depicts plots of Micro-Kerr remnant reversal curves for different non-magnetic interlayer thicknesses on patterned media constructed in accordance with the invention; and

FIG. **5** is a schematic diagram of one embodiment of a disk drive constructed in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. **2-5**, embodiments of a system, method and apparatus for reducing the amount of magnetic material located in the trenches between topographic features in bit patterned media are shown.

In one embodiment (FIG. **2**), the invention comprises a magnetic media disk **31** for a hard disk drive. The disk may include a substrate **33**, a soft underlayer **35** on the substrate **33**, and an optional exchange break layer **37** on the soft underlayer **35**. Topographic formations or islands **39** extend from the substrate **33** and/or layers formed thereon. An intermediate non-magnetic material **41** is deposited on this structure **39**, followed by the deposition of a magnetic recording layer **43** (FIG. **3**). FIG. **2** schematically illustrates the structure after depositing the intermediate layer **41**. FIG. **3** schematically shows the media structure after deposition of the magnetic recording layer **43**. This process and configuration reduces the amount of magnetic material deposited in the trenches **45**.

The non-magnetic material is deposited under conditions that result in lateral (i.e., left and right in FIGS. **2** and **3**) as well as vertical growth of the film. Material extends outward laterally from the tops of the islands **39**, which narrows the access aperture for approaching material from any subsequent further deposition of material. These self-shadowing effects prevent a fast coalescence of adjacent islands/pillars and thus prevent any undesired coupling between adjacent islands/pillars. Using an angle of incidence **47** (FIG. **3**) other than normal promotes lateral growth of the film and side wall growth, thus increasing the island width and the effective area contributing to the readback signal.

The magnetic properties of the recording layers are fairly independent of the non-magnetic interlayer thickness. For example, materials such as Ta and Pd may be used to fulfill this requirement as demonstrated in the Micro-Kerr measurements in FIG. **4**. FIG. **4** is a plot of Micro-Kerr remnant reversal curves **51**, **53**, **55** for different non-magnetic interlayers for a Co/Pd multilayer media. In this example the islands are 50 nm in width and formed at a 100 nm pitch. The island switching field is similar in all three cases (i.e., about 11 kOe). However, for an interlayer having a thickness of 28.5 nm, a small shift is observed to lower the reversal fields. The Kerr signal from the trench reversal (at about 2-3 kOe) is reduced with increasing interlayer thickness, which indicates that there is less magnetic trench material for thicker interlayers. Overall, the thickness of the non-magnetic layer should be tuned depending on the lateral periodicity of the pattern and the initial trench width of the pre-patterned substrate. This maximizes the effective area that contributes to the readback signal without causing any inter-island exchange coupling.

Since access to the trenches is reduced by deposition of the intermediate layer, significantly less magnetic material is deposited in the trenches as also confirmed experimentally by the Kerr measurements in FIG. **4**. The growth of the intermediate layer effectively "pinches off" the access route for deposition of further material in the trenches. Choosing to deposit the magnetic material at an angle other than normal can further reduce deposition of magnetic trench material. Based on experimental results, reducing the amount of trench material by a factor of two or three may be sufficient to achieve adequate readback signal to noise ratio.

Using magnetic multilayers as magnetic media, one may use different angles for two multilayer materials, which leads to proper multilayer structures on top of the islands. Predominantly, only one material reaches the trenches (i.e., with normal incidence) and the other material reaches the sidewalls (i.e., at an angled incidence). Thus, different material compositions are formed on the sidewalls and trenches which may result in non-magnetic phases in the trenches as well as on the sidewalls.

In addition, subsequent oxidation processes may play a significant role in such configurations. For example, a Pd/Co multilayer may be used with Pd deposited normal to the substrate surface and Co deposited at an angle. This results in a Pd-rich trench phase (non-magnetic) and a Co-rich side wall phase. However, the Co on the sidewalls does not form a continuous film and thus oxidizes to non-ferromagnetic Co-oxide clusters after the media is exposed to ambient air. In contrast, the multilayer on top of the islands are protected by a final cap layer, such as a Pd cap having a thickness of 2 nm.

As shown in the drawings, deposition of the intermediate layer causes the lateral dimensions of the lands or islands to grow. Such lateral growth (and additional curvature, which may develop when depositing the interlayer) needs to be taken into account in the magnetic design of the media from a recording system point of view. For example, larger lands or islands increase overall readback flux, which is desirable, but also increases dipole interactions between islands in BPM, which may adversely affect switching field distribution. See, e.g., the publication, *Separating Dipolar Broadening from the Intrinsic Switching Field Distribution in Perpendicular Patterned Media*, O. Hellwig, et al, Appl. Phys. Lett. 90, 162516 (2007). Such effects may need to be countered by reducing the moment or thickness of the magnetic recording layer. For DTM, increased land width may affect the optimal choice for head element widths and off-track and adjacent track erasure effects.

In one embodiment, the invention comprises a magnetic media disk including a substrate, a plurality of topographic features formed on the substrate and defining trenches therebetween, a layer of non-magnetic material formed on the topographic features and on the trenches, and a layer of magnetic material formed on the layer of non-magnetic material on at least the topographic features to define a recording layer.

Referring again to the embodiment of FIGS. **2** and **3**, the layer of non-magnetic material is segmented into portions **41** that are located on the topographic features **39**, and portions **67** that are located in the trenches **45**. In addition, the layer of magnetic material is segmented into magnetic portions **43** on non-magnetic portions **41**, and magnetic portions **65** on non-magnetic portions **67**. Each of the non-magnetic portions **41** has a width **61** that is greater than a width **63** of the topographic features **39**, but narrower than a width **69** of the magnetic portions **43**. However, the widths of non-magnetic portions **67** are greater than the widths of magnetic portions **65**.

In other embodiments, the topographic features are non-magnetic, and have sidewalls on which some of the non-magnetic material is located. At least portions of the layer of magnetic material also are located on the non-magnetic material formed on the trenches. The substrate has a surface that defines a planar direction, the topographic features extend in a direction that is normal to the planar direction, and the layer of non-magnetic material located on the topographic features extends substantially parallel to the planar direction.

In still another embodiment, a soft underlayer formed on the substrate, an optional exchange break layer formed on the soft underlayer, and the topographic features extend from the exchange break layer such that the trenches also are located on the exchange break layer. The non-magnetic layer may have a thickness of approximately 15 to 30 nm (e.g., 15 to 20 nm in one embodiment), depending on the pattern periodicity. In addition, the non-magnetic layer may comprise a TaPd alloy or Ta/Pd bilayers. The disk may comprise thin seed layers, underlayer structures and/or adhesion layers deposited directly beneath the magnetic layer, either above or below the intermediate layer.

As shown and described herein, the topographic features may comprise islands having a spacing therebetween. The non-magnetic material segments located on the islands have a smaller spacing between them than the spacing between the islands. In another embodiment, an aperture is defined between adjacent islands, one trench is defined in each aperture, and the non-magnetic material reduces the size of each aperture.

Referring now to FIG. **5**, a schematic drawing of one embodiment of an information storage system comprising a magnetic hard disk file or drive **111** for a computer system is shown. Drive **111** has an outer housing or base **113** containing at least one magnetic disk **115**. Disk **115** is rotated by a spindle motor assembly having a central drive hub **117**. An actuator **121** comprises one or more parallel actuator arms **125** in the form of a comb that is pivotally mounted to base **113** about a pivot assembly **123**. A controller **119** is also mounted to base **113** for selectively moving the comb of arms **125** relative to disk **115**.

In the embodiment shown, each arm **125** has extending from it at least one cantilevered load beam and suspension **127**. A magnetic read/write transducer or head is mounted on a slider **129** and secured to a flexure that is flexibly mounted to each suspension **127**. The read/write heads magnetically read data from and/or magnetically write data to disk **115**. The level of integration called the head gimbal assembly is the head and the slider **129**, which are mounted on suspension **127**. The slider **129** is usually bonded to the end of suspension **127**. The head is typically formed from ceramic or intermetallic materials and is pre-loaded against the surface of disk **115** by suspension **127**.

Suspensions **127** have a spring-like quality which biases or urges the air bearing surface of the slider **129** against the disk **115** to enable the creation of the air bearing film between the slider **129** and disk surface. A voice coil **133** housed within a voice coil motor magnet assembly **134** is also mounted to arms **125** opposite the head gimbal assemblies. Movement of the actuator **121** (indicated by arrow **135**) by controller **119** moves the head gimbal assemblies radially across tracks on the disk **115** until the heads settle on their respective target tracks.

While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention. For example, the invention also is suitable for magnetic media applications such as magnetic tape.

What is claimed is:

1. A method of forming a bit patterned media on a magnetic media disk, comprising:

forming topographic features on a substrate and defining trenches therebetween;

forming non-magnetic material on the topographic features to define non-magnetic portions;

forming magnetic material on the non-magnetic portions to define magnetic portions for a recording layer, such that the magnetic portions have a magnetic width that is greater than a non-magnetic width of the non-magnetic portions;

the topographic features comprise islands having a spacing therebetween, and the non-magnetic material located on the islands has a smaller spacing therebetween than the spacing between the islands; and

an aperture is defined between adjacent ones of the islands, one trench is defined in each aperture, and the non-magnetic material reduces a size of each aperture.

2. A method according to claim **1**, further comprising using a deposition angle of incidence other than normal to promote lateral growth of the non-magnetic material, and the non-magnetic width is greater than a feature width of the topographic features.

3. A method according to claim **1**, wherein the topographic features are non-magnetic and have sidewalls on which some of the non-magnetic material is located, and varying a deposition angle with respect to a surface normal to the substrate to mitigate a degree of sidewall overgrowth effects.

4. A method according to claim **1**, further comprising forming non-magnetic material in the trenches at a non-magnetic trench width, and magnetic material on the non-magnetic material in the trenches at a magnetic trench width, and the non-magnetic trench width is greater than the magnetic trench width.

5. A method according to claim **1**, further comprising:

forming a soft underlayer on the substrate, an exchange break layer on the soft underlayer, and the topographic features extend from the exchange break layer such that the trenches also are located on the exchange break layer; and

depositing at least one of thin seed layers, underlayer structures and adhesion layers beneath the magnetic material, either above or below the non-magnetic material.

6. A method of forming a bit patterned media on a magnetic media disk, comprising:

forming topographic features on a substrate and defining trenches therebetween;

forming non-magnetic material on the topographic features to define non-magnetic portions;

forming magnetic material on the non-magnetic portions to define magnetic portions for a recording layer, such that the magnetic portions have a magnetic width that is greater than a non-magnetic width of the non-magnetic portions; wherein

the topographic features comprise islands having a spacing therebetween, and the non-magnetic material located on the islands has a smaller spacing therebetween than the spacing between the islands;

an aperture is defined between adjacent ones of the islands, one trench is defined in each aperture, and the non-magnetic material reduces a size of each aperture;

forming magnetic material in the trenches; and

oxidizing the magnetic material in the trenches to a non-ferromagnetic material, and protecting the magnetic material on the islands with a cap layer to retain magnetic properties thereof.

7. A method according to claim **6**, further comprising using a deposition angle of incidence other than normal to promote lateral growth of the non-magnetic material, and the non-magnetic width is greater than a feature width of the topographic features.

8. A method according to claim **6**, wherein the topographic features are non-magnetic and have sidewalls on which some of the non-magnetic material is located, and varying a deposition angle with respect to a surface normal to the substrate to mitigate a degree of sidewall overgrowth effects.

9. A method according to claim **6**, further comprising forming non-magnetic material in the trenches at a non-magnetic trench width, and magnetic material on the non-magnetic material in the trenches at a magnetic trench width, and the non-magnetic trench width is greater than the magnetic trench width.

10. A method according to claim **6**, further comprising:

forming a soft underlayer on the substrate, an exchange break layer on the soft underlayer, and the topographic features extend from the exchange break layer such that the trenches also are located on the exchange break layer; and

depositing at least one of thin seed layers, underlayer structures and adhesion layers beneath the magnetic material, either above or below the non-magnetic material.

* * * * *